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CACHE RIVER BASIN PROJECT
PROGRESS REPORT

by Misganaw Demissie, Paul B. Makowski, Ta Wei Soong, and Nani G. Bhowmik

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INTRODUCTION

This report is a brief summary of the progress on the Cache River basin project. A more detailed technical report is in preparation. This summary discusses the status of the monitoring program, preliminary results, and the May 1986 flood in the basin. It also outlines future project plans including data collection, modeling, and development of alternative solutions to the hydrologic problems in the basin.

MONITORING PROGRAM

The watershed monitoring program being conducted by the Illinois State Water Survey (ISWS) consists of the collection of precipitation, stage, streamflow, and sediment data. In addition to the monitoring stations located in the basin prior to the ISWS's monitoring program, additional stations were installed at strategic locations to better describe the hydraulic, hydrologic, and sediment transport dynamics within the basin.

Six precipitation gages are operated by the National Oceanic and Atmospheric Administration within or near the Cache River basin, at Anna, Brookport, Cairo, Cape Girardeau, Carbondale, and Dixon Springs. The data from these stations are used to assess the variations in precipitation and also to provide a historical data base. Three new precipitation gages were installed in the basin as part of the monitoring program for better resolution of the precipitation in the basin.

The locations of the 16 streamflow and sediment monitoring stations maintained and operated by the ISWS are shown in the Cache River watershed map (figure 1). The names of the streams, the locations of the monitoring stations, the types of equipment in use at the stations, and the drainage areas being monitored are summarized in table 1. Of the 16 streamflow and sediment monitoring stations in the watershed, nine of the stations have continuous water stage recorders and five have crest gages. The automated stage recorders record the water surface elevation at the station continuously, while the crest gages provide the peak water surface elevation during floods. Sediment samples are collected on a regular basis at seven of the stations and occasionally at all the other stations. Automated samplers, which collect sediment samples on a periodic basis, have been installed at three locations.

The monitoring stations are placed at strategic locations to provide the needed information on channel entrenchment in the upper Cache River and the Post Creek Cutoff, and on the flooding and sedimentation problems in the lower Cache River. The monitoring stations on Big Creek, Cypress Creek, Little Creek, and the Cache River at Route 37 and Route 51 will provide the necessary data to define the flooding and sedimentation problems in Buttonland Swamp and will further assist in the development of alternative solutions to the hydrologic problems in the area. The monitoring stations in the lower Cache River at Route 51, Mill Creek, and Indian Camp Creek will provide valuable information on flooding in the lower Cache River and its tributaries and will define the influence of the Mississippi and Ohio Rivers on Cache River flooding.

Historical data are available for two locations in the basin: Big Creek at Perks Road and Cache River at Forman. The Big Creek site was discontinued in 1971 as a continuous station but still functions as a peak flow station, while the Forman site is still maintained as a continuous station.

All the monitoring stations are in good condition, although they require regular maintenance and cleaning. There

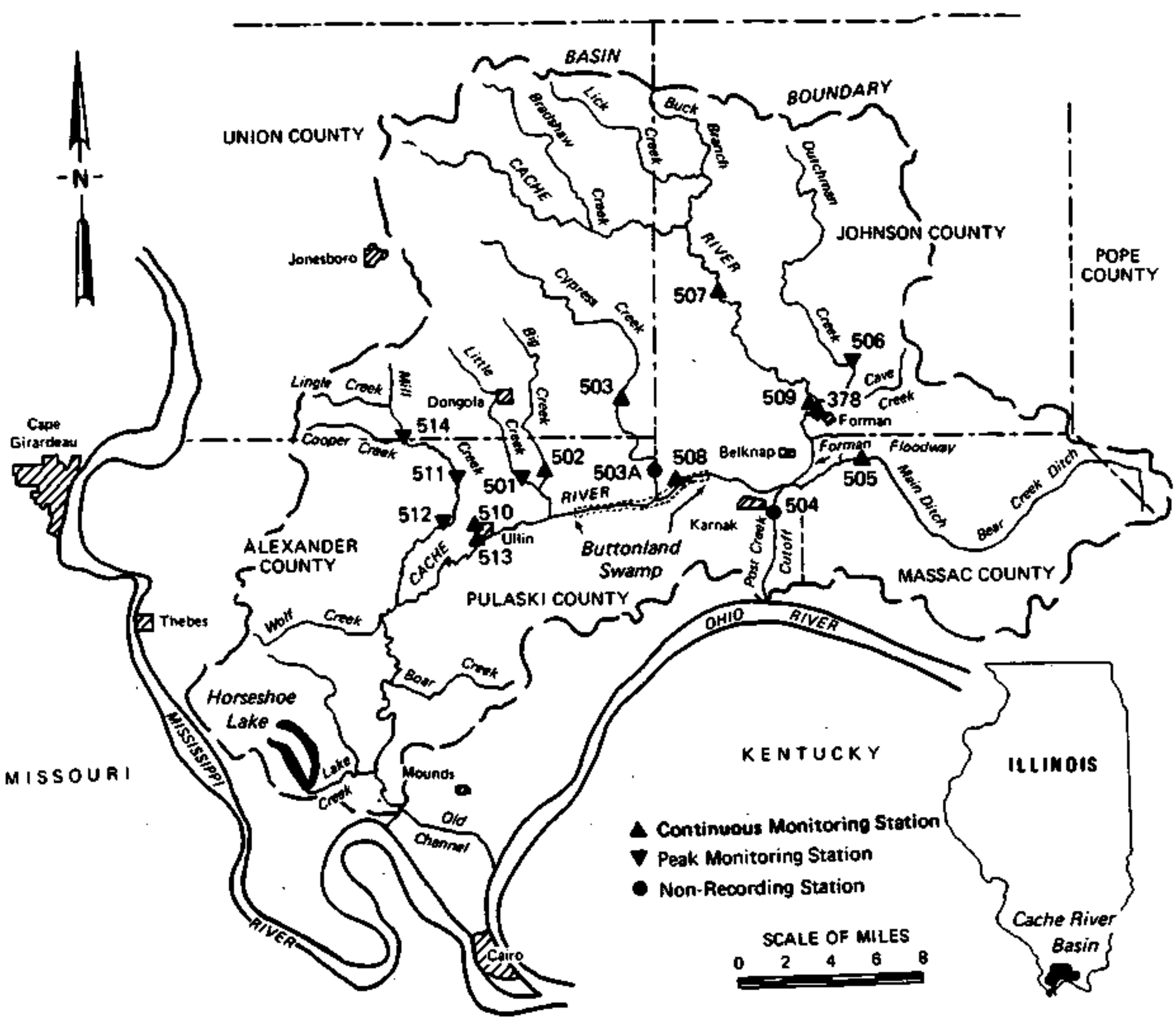

Figure 1. Locations of monitoring stations in the Cache River basin

Table 1. Streamflow and Sediment Monitoring Stations, Cache River Basin

ID no.	Stream name	Location	Drainage area (sq mi)	Equipment
378	Cache River	Forman	241	4,5
501	Little Creek	Perks Road	13	1
502	Big Creek	Perks Road	31	3,5,6
503	Cypress Creek	Dongola Road	24	3,6
503A	Cypress Creek	Perks Road	44	5
504	Post Creek Cutoff	Route 169	352	7
505	Main Ditch	Route 45	97	3,5
506	Dutchman Creek	Route 45	70	1
507	Cache River	Route 146	122	3,5
508	Cache River	Route 37	12	3,5
509	Heron Pond	Heron Pond	--	2
510	Indian Camp Creek	Ullin	4*	2
511	Mill Creek	Section 10	31	1
512	Mill Creek	Section 22	34**	1
513	Cache River	Route 51	164	2,6
514	Mill Creek	Section 32	16	1

Equipment Key:

1 - crest gage
2 - F-recorder
3 - A-recorder
4 - USGS station
5 - sediment box
6 - automated sampler
7 - no equipment

* A cutoff above this station increases the effective drainage area
** A cutoff above this station decreases the effective drainage area

are no plans to change the number of monitoring stations in the watershed for the remaining duration of the project.

Preliminary Results from Monitoring Stations

The results presented in this report are provisionary and are subject to revision as more data become available. The data are broken into water years for presentation. A water year runs from October 1 through September 30. The date when data collection began varies from station to station although most stations were operational by July 1985. The data for Water Year 1985 are therefore incomplete because data were not collected for that entire year.

Preliminary results for monthly streamflows and suspended sediment loads are shown in figures 2 through 7 for the Cache River at Route 146, Cache River at Forman, Main Ditch at Route 45, Big Creek at Perks Road, Cypress Creek at Dongola Road, and Cache River at Route 51. Streamflows are given in inches and sediment loads in tons per 10 acres of drainage area.

The greatest monthly values of both streamflow and sediment loads recorded in the Cache River basin occurred in the months of April 1985, August 1985, November 1985, February 1986, and May 1986. The months of low flow include July 1985, October 1985, January 1986, April 1986, and the period from June through September 1986.

The month in which the greatest streamflow occurred at a station was not always the same month in which the maximum sediment load occurred. Factors other than streamflow must play a role at the stations in order for the maximum monthly streamflow and sediment loads not to occur concurrently. The sediment concentration, which is as important as streamflow in the determination of the sediment load, is variable and is dependent on factors such as land use, ground cover, and precipitation amount and intensity. However, the conditions that cause high streamflows usually also result in an increase in the sediment concentration.

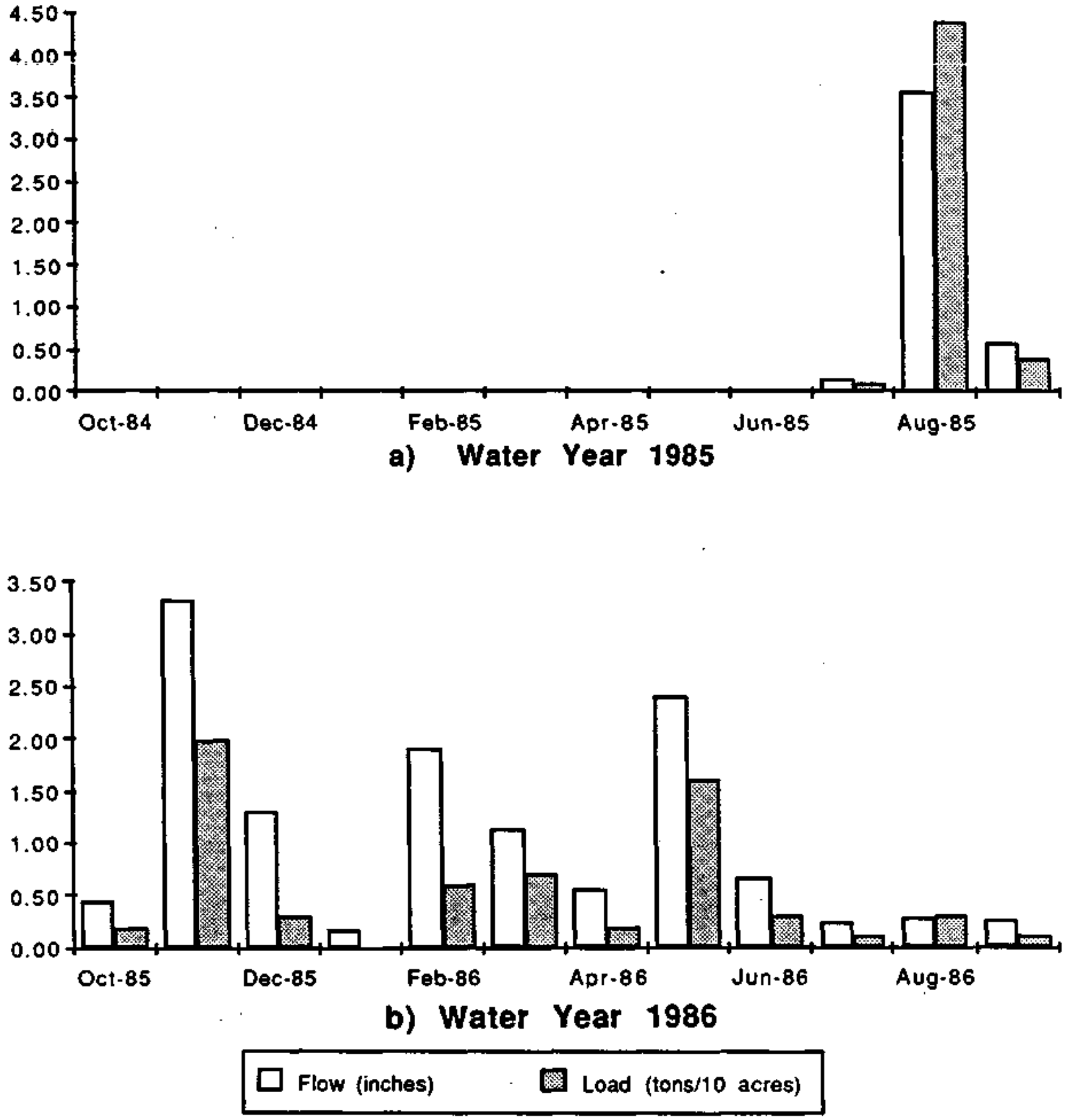

Figure 2. Flow and suspended sediment loads
at Cache River at Route 146

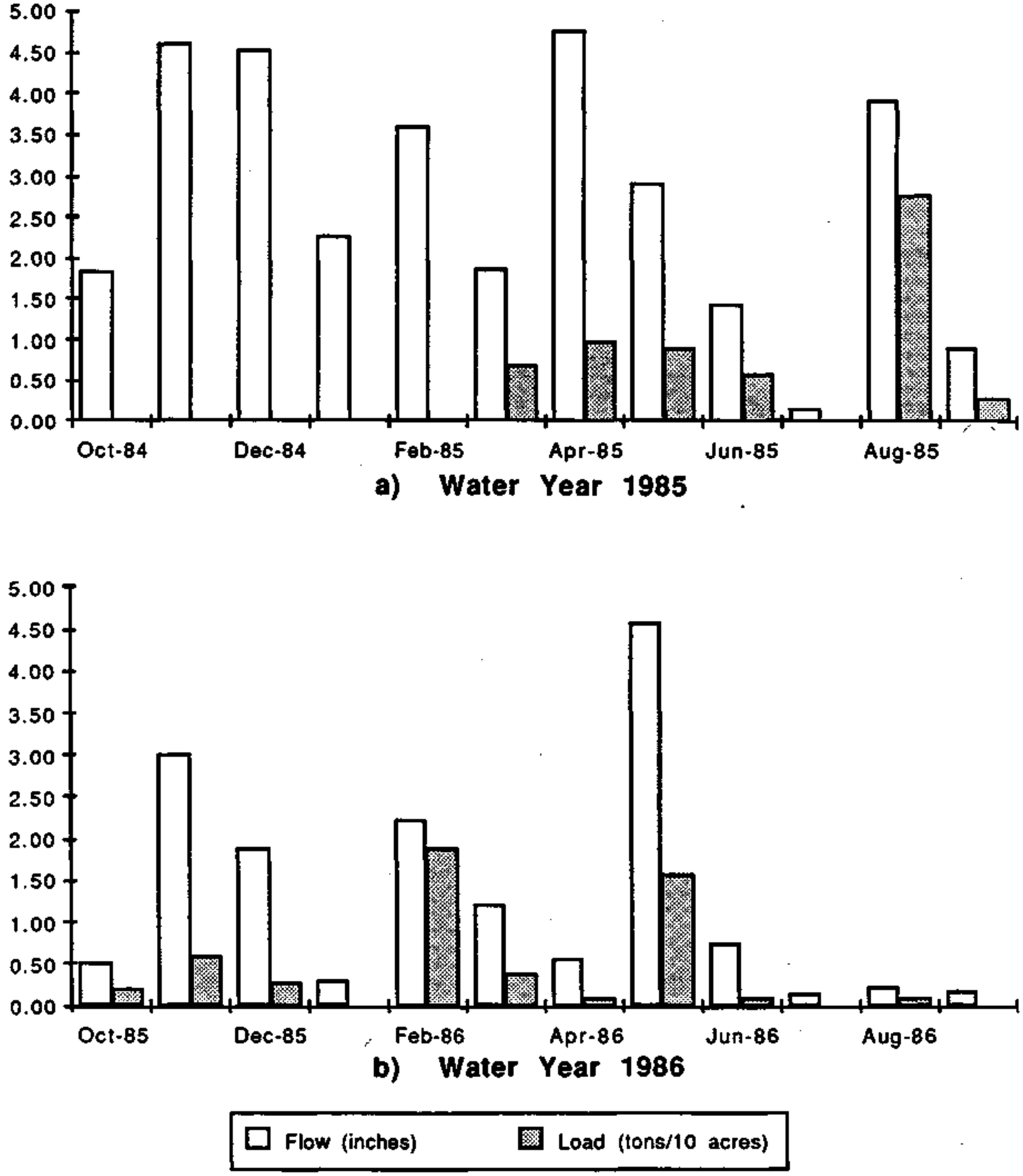

Figure 3. Flow and suspended sediment loads at Cache River at Forman

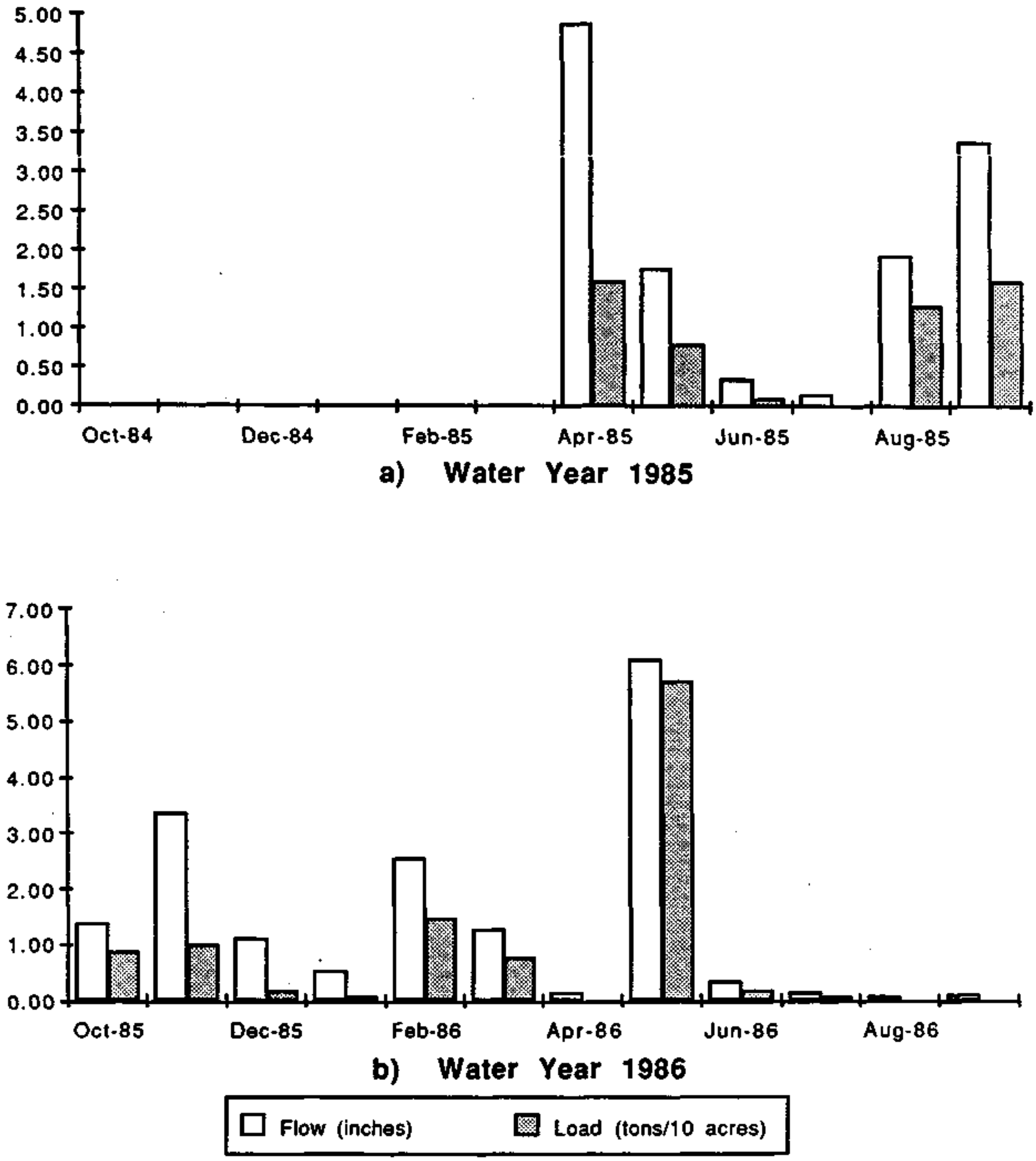

Figure 4. Flow and suspended sediment loads at Main Ditch at Route 45

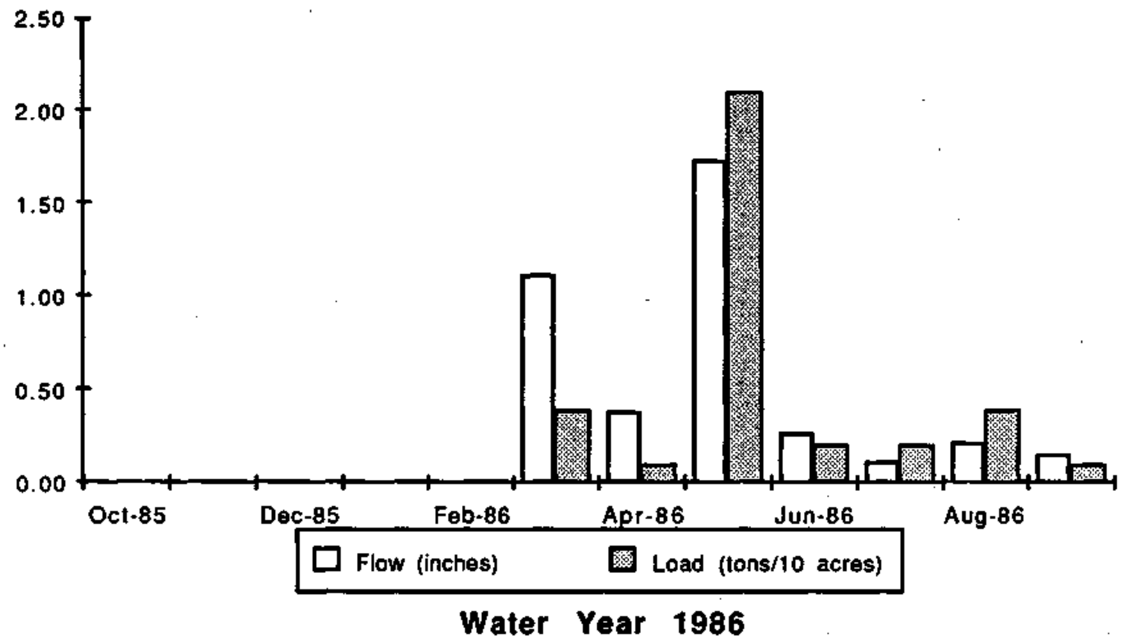

Figure 5. Flow and suspended sediment loads at Big Creek at Perks Road

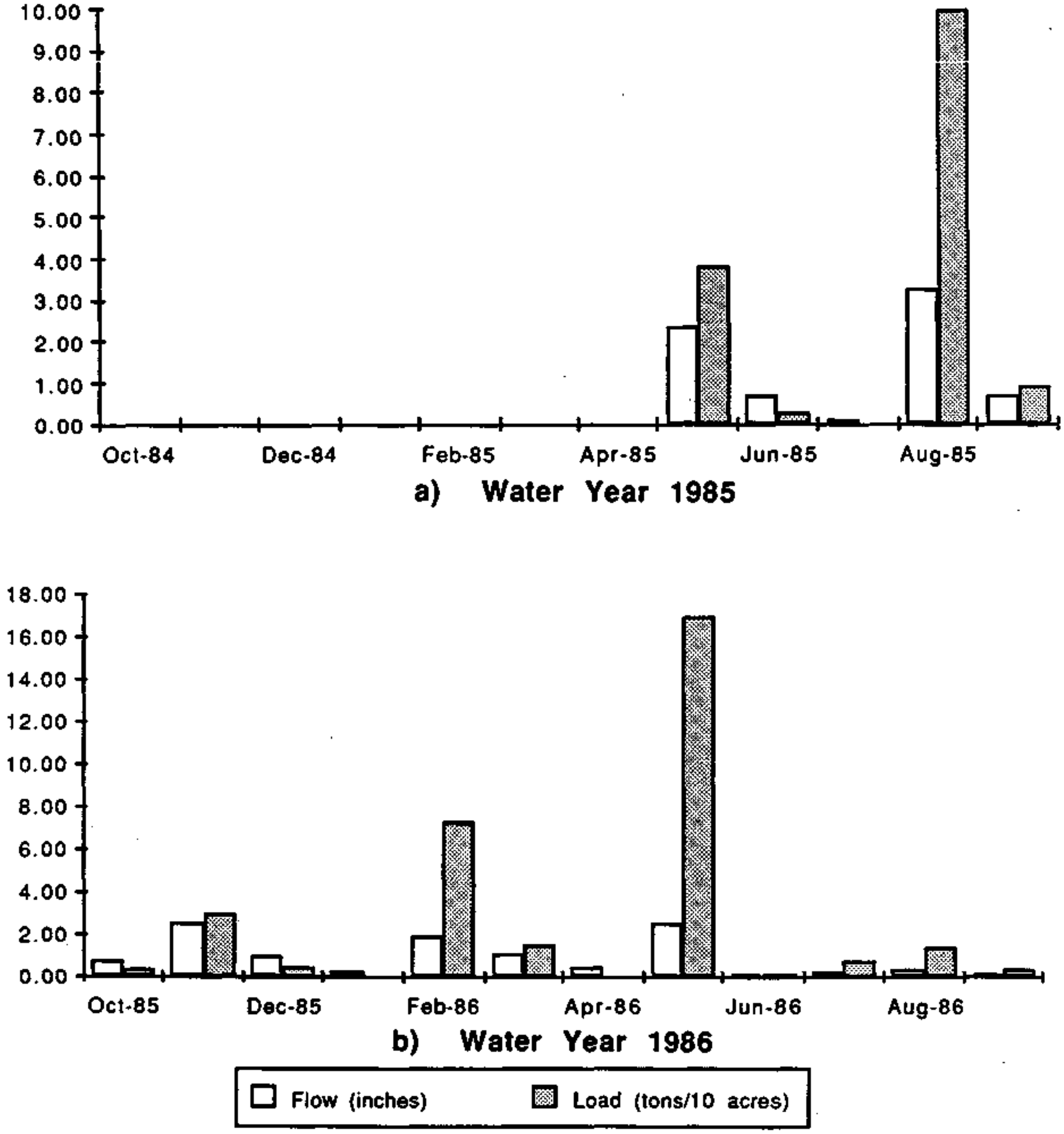

Figure 6. Flow and suspended sediment loads
at Cypress Creek at Dongola Road

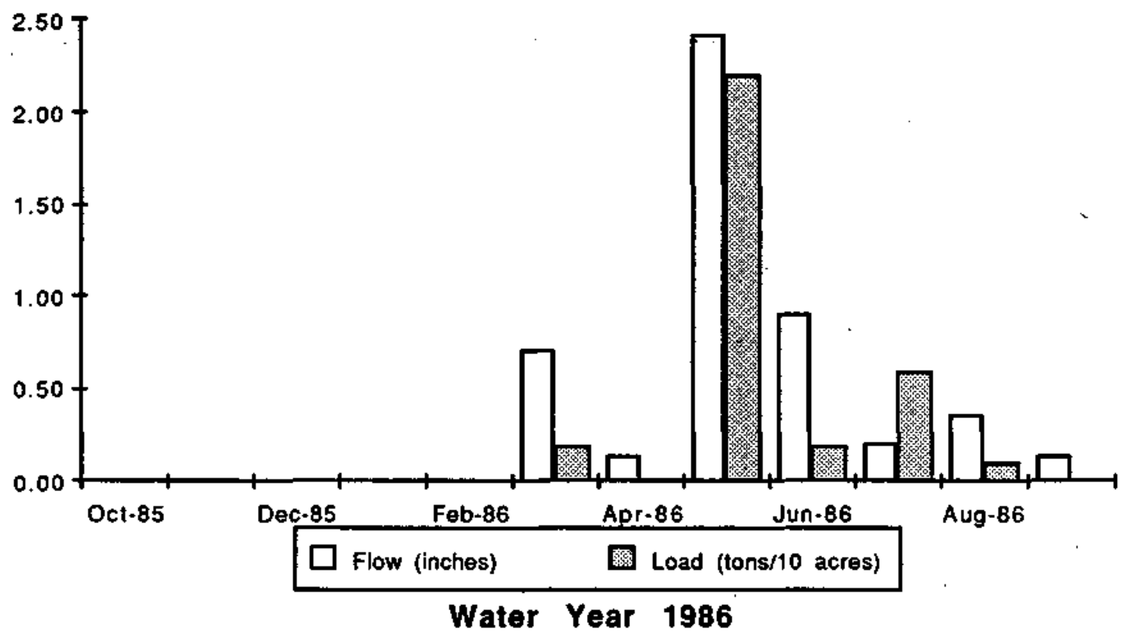

Figure 7. Flow and suspended sediment loads at Cache River at Route 51

The streamflows for three locations in the upper Cache River basin are compared in figure 8. No one station consistently had the greatest streamflows. Although the streamflows at the three stations during each month were somewhat similar, the month in which the greatest streamflow was recorded was not identical for each station. This was due to variations in precipitation and the other factors which cause streamflow to differ from one drainage area to another.

In figure 9 the streamflows are compared for three stations in the lower Cache River basin. As in the upper Cache River basin, no one station consistently had the highest streamflows. Variations in the amount of monthly streamflow between stations were minimal.

The monthly suspended sediment loads are compared for the upper Cache River basin in figure 10. Variations in the sediment loads are greater than the variations observed in the streamflow. This is because in addition to variations in the streamflow, other factors which affect the sediment concentration also vary, causing large fluctuations in the sediment load. No one station consistently had the highest sediment loads, but the Cache River at Forman usually had the lowest monthly values.

In figure 11 a comparison is made of the sediment loads at the stations in the lower Cache River basin. Big Creek consistently had the highest monthly sediment loads of the stations in the lower Cache River basin. Since the Cypress Creek and Big Creek watersheds are approximately the same size and are adjacent to each other, the causes of the differences in sediment loads are not readily apparent.

Figure 12 shows the sediment load transported during storm events at several stations in the Cache River basin. Each bar represents the total amount of sediment transported during the period of monitoring. The lower portion of each bar represents the percentage of the total sediment load which was transported during the 10 percent of the monitoring period in which the highest sediment loads occurred. For example, at

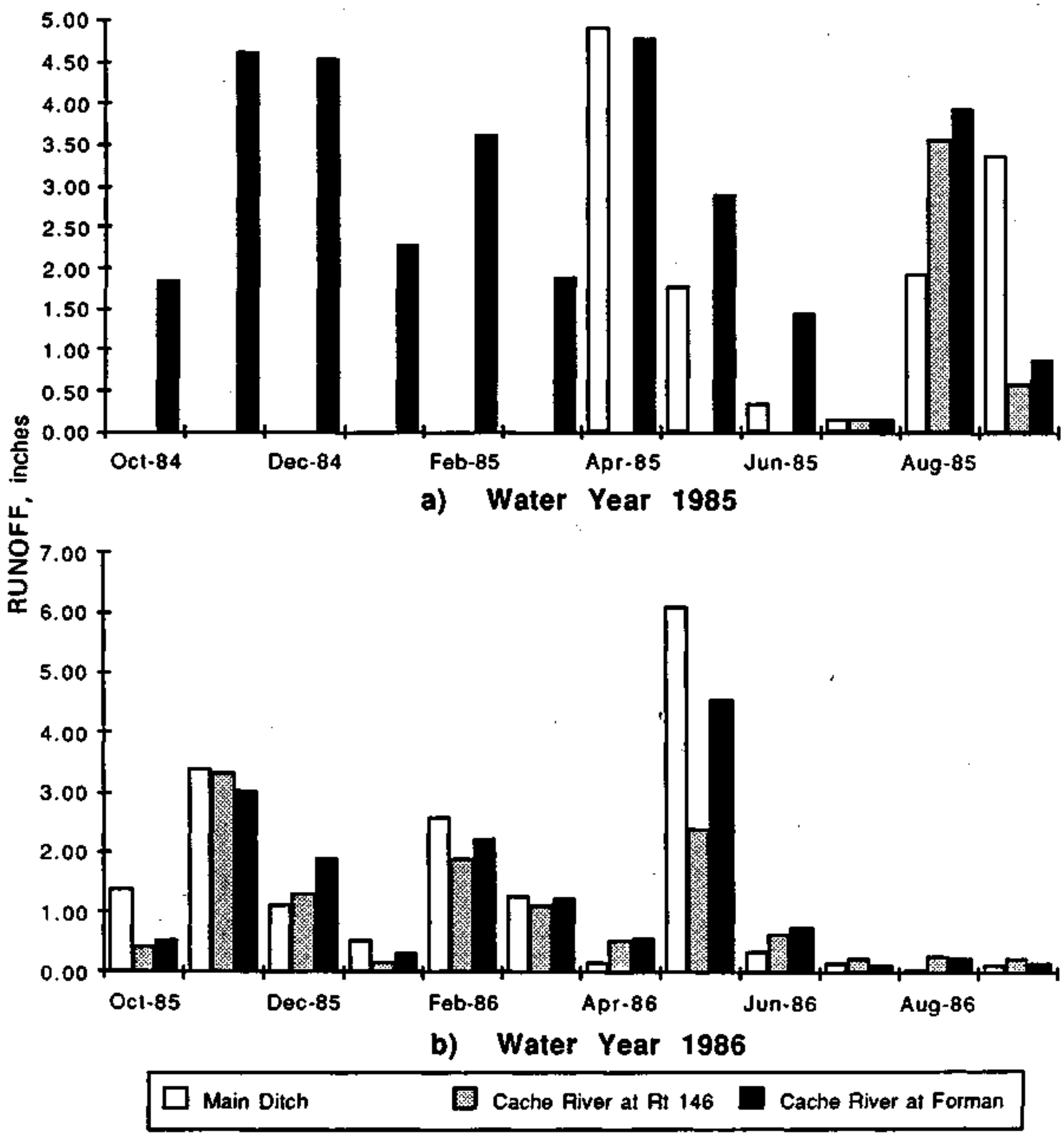

Figure 8. Comparison of flows in the upper Cache River basin

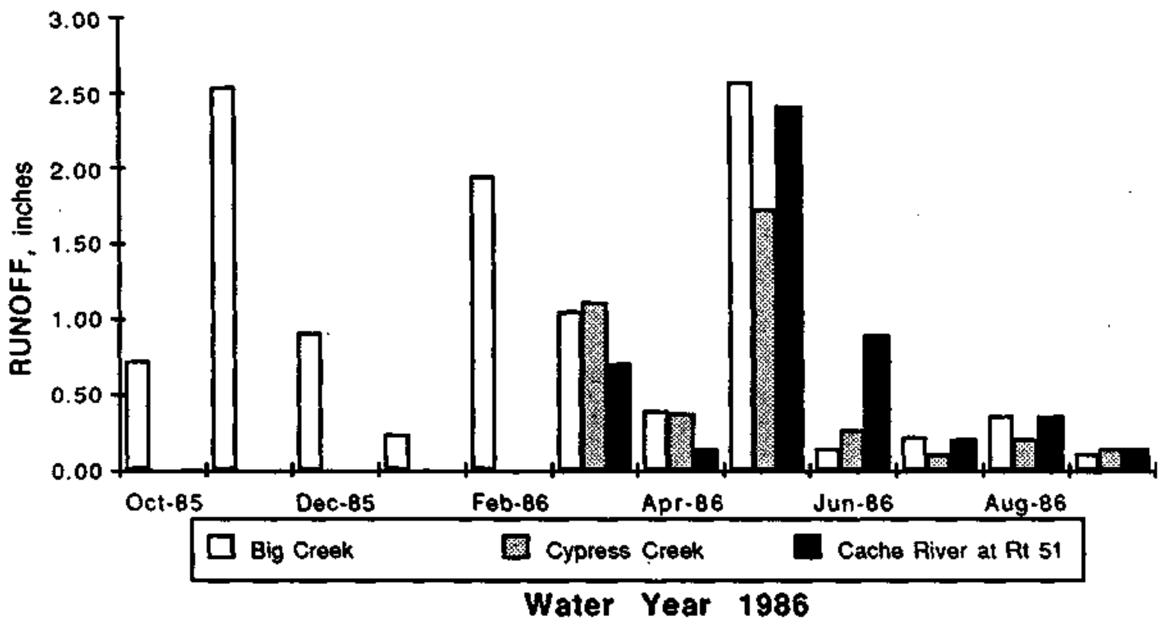

Figure 9. Comparison of flows in the lower Cache River basin

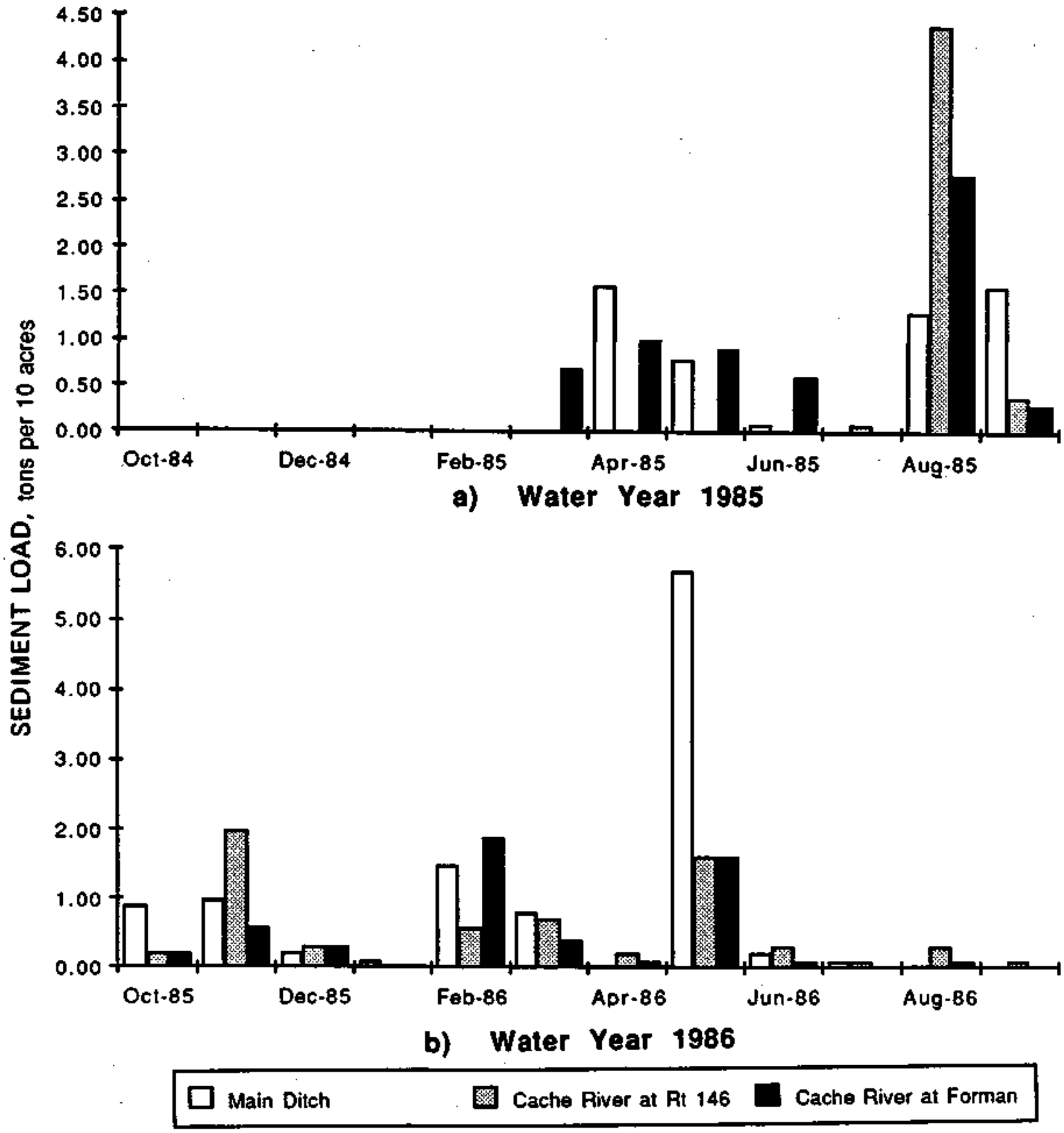

Figure 10. Comparison of suspended sediment loads in the upper Cache River basin

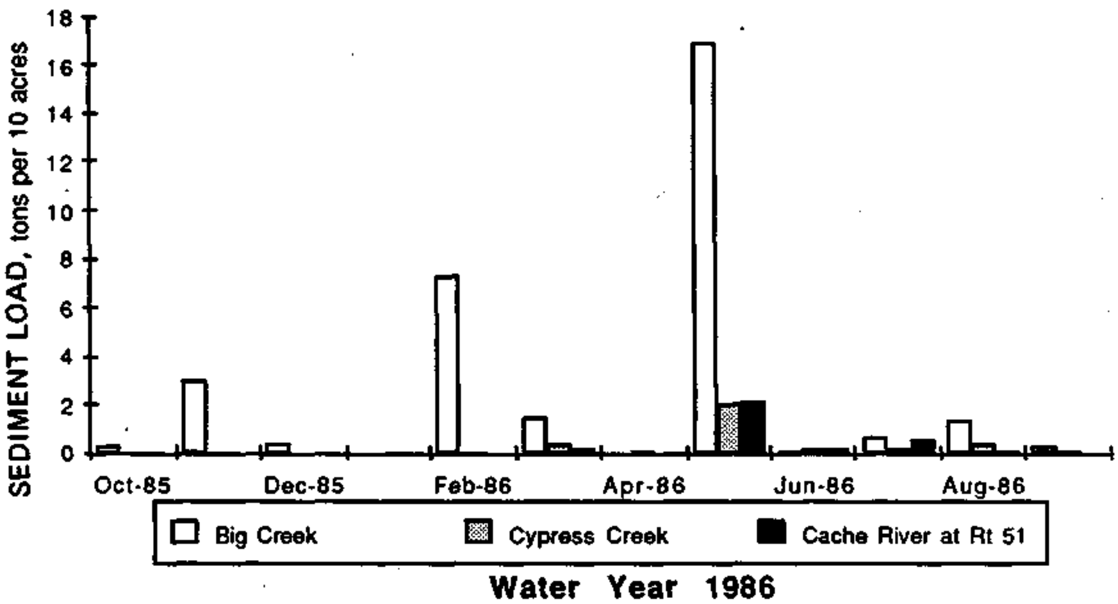

Figure 11. Comparison of suspended sediment loads
-in the lower Cache River basin

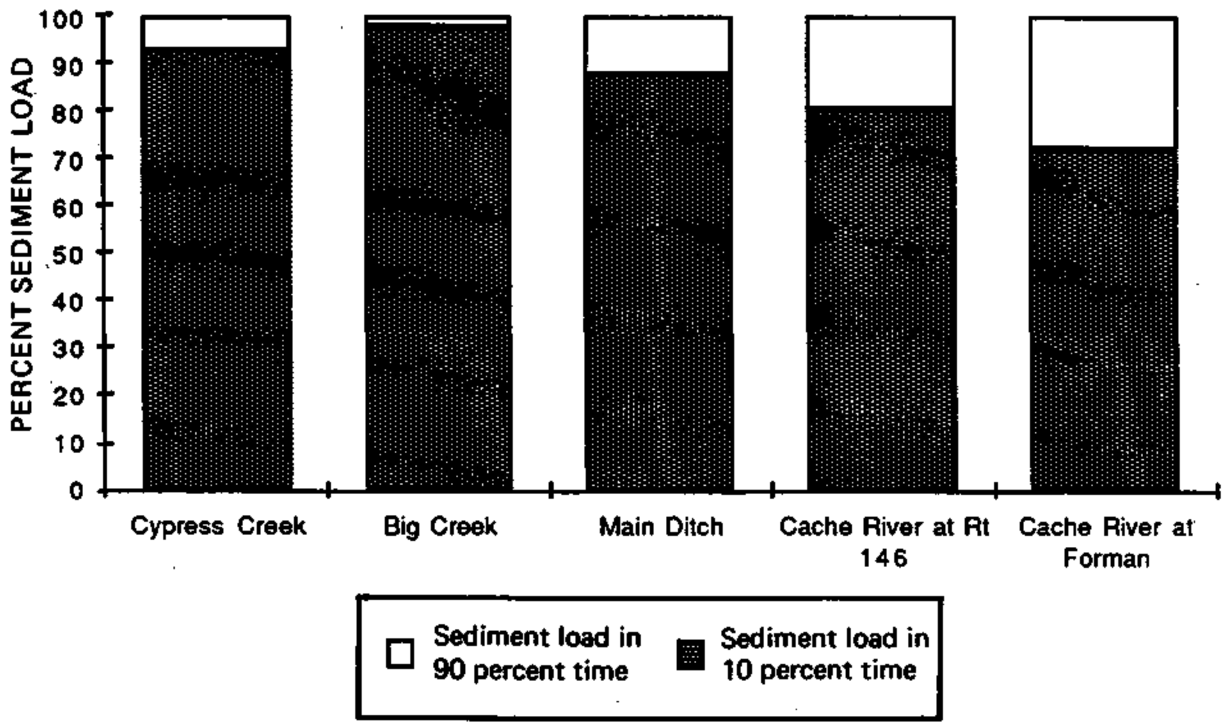

Figure 12. Percentage of sediment load transported during the 10 percent of the monitoring period in which the highest sediment loads occurred, and percentage transported during the remaining 90 percent of the monitoring period

Big Creek, 98 percent of the total sediment load was transported during that 10 percent of the monitoring period. The Cache River at Forman had the lowest percentage (72 percent) of sediment transported during that 10 percent of the monitoring period. As can be seen, at all the stations a large percentage of the sediment load was transported during that 10 percent of the monitoring period, which in general corresponds to the periods with the largest storm events. This information is important when considering alternative solutions to sediment control.

Flood of May 1986

The storm event which began on May 15, 1986 was the largest event monitored by the State Water Survey in the basin since the start of the project. This storm caused extreme floods in the Cache River basin and was especially severe in the lower Cache River basin. For this event there were local reports of between 11 to 14 inches of rainfall. However, recorded precipitation amounts were lower than those of the local reports. Of the NOAA precipitation gages in and around the basin, the gage at Cape Girardeau recorded the greatest 1-day rainfall of 5.6 inches, which corresponded to a recurrence interval of almost 18 years. On the other hand, the 1-day rain recorded by the Cairo gage had less than a 2-year recurrence interval. The rainfall amounts and recurrence intervals for two consecutive days of the event increased substantially, with both the Anna and Cape Girardeau stations recording rainfall amounts corresponding to 35-year recurrence intervals. The event that occurred in May 1986 was a long-duration storm. The critical duration of rainfall was 2 days for Cape Girardeau, 3 days for Anna, and 5 days for Cairo and Dixon Springs. The critical duration is the duration with the highest recurrence interval. The lower values at the Cairo and Dixon Springs stations indicate that the majority of the rainfall fell over the northwest portion of the Cache River basin. This is confirmed by the raingages located at Horseshoe Lake, which recorded lower rainfall amounts.

The flooding that resulted from this rainfall was monitored at several locations within the Cache River basin, including Big Creek at Perks Road and Cache River at Forman. These stations have streamflow records of 46 years and 64 years, respectively. On the basis of these long-term records, it is possible to perform frequency analyses of the streamflows. At Big Creek this flood was the third-largest annual maximum flood of this decade and the 12th largest overall. At Cache River near Forman, the flood was the 26th-largest annual maximum flood. This flood corresponds to almost a 4-year flood on Big Creek and a 2.50-year flood on the Cache River at Forman. These recurrence intervals suggest that this was not an extreme flood although the flooding was widespread in the lower Cache River basin. It was the long-duration rainfall that caused the widespread flooding. That is, it was the high volume of runoff and not the peak flow which caused the widespread flooding.

The stage hydrograph of the May 1986 flood at Route 37 is shown in figure 13. The hydrograph shows that the peak water level reached 8.8 feet above the preflood levels. This flood had a peak elevation approximately 2 feet higher than any other flood monitored by the gage at Route 37. The peak flood elevation corresponds to 336 feet above mean sea level. The flood stages took over 3 weeks to subside.

Also shown in the figure is the directional flow at different times in the Cache River at the Route 37 bridge. The initial flow direction was to the east. As time progressed and as the flood stage rose relatively quickly, the flow continued towards the easterly direction with increased flow velocities. As the flood stage approached the peak the flow velocities decreased and eventually approached zero, at which time there was no flow in either direction. After that, the flow changed direction several times, sometimes flowing to the east and sometimes to the west, with no flow during some

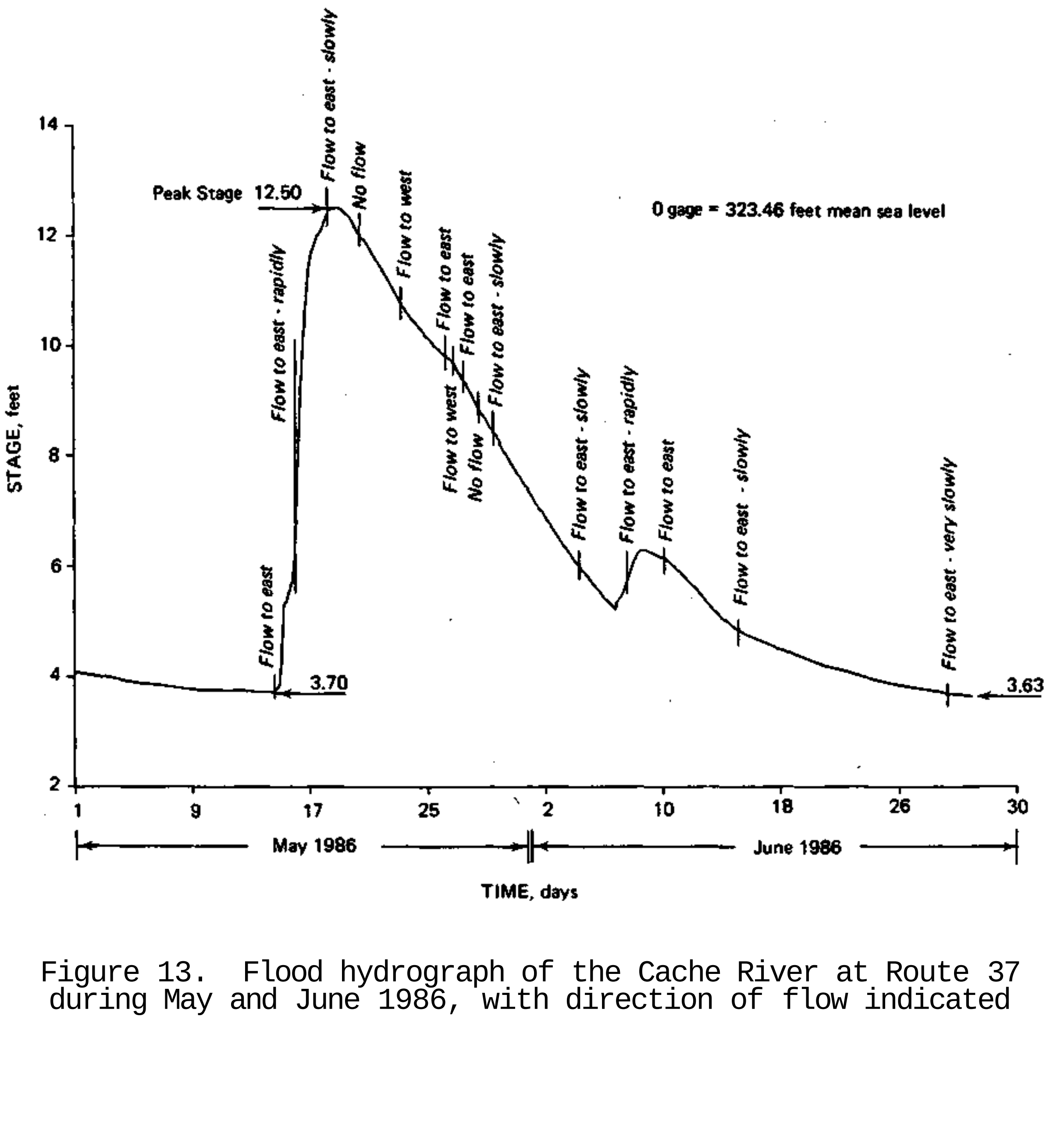

Figure 13. Flood hydrograph of the Cache River at Route 37 during May and June 1986, with direction of flow indicated

periods. Eventually, after the flood had subsided, the flow was in the easterly direction.

FUTURE PROJECT PLANS

The future plans for the Cache River basin project include the following three major tasks:

1. Continue the collection and analysis of hydrologic, hydraulic, and sediment data.
2. Develop and improve the mathematical models for the Post Creek Cutoff - upper Cache River and the lower Cache River segments.
3. Formulate and evaluate alternative solutions to the hydrologic problems in both segments of the basin.

Data Collection and Analysis

The data collection program has made significant progress since the start of the project. The streamgaging stations are all in good operating condition. The development of rating curves for each of the gaging stations has progressed to the point where streamflows may be computed. Although additional discharge measurements and refinements of the rating curves will be made in the following years, the rating curves that have been developed are adequate to enable us to make preliminary analyses of the data.

Regular weekly sediment concentration samples and more frequent samples during storm events have been and continue to be collected. Automated water samplers have been installed at Cypress Creek at Dongola Road, Big Creek at Perks Road, and Cache River at Route 51. The automated samplers enable more frequent sampling than the present rate at these three critical locations, so that a more detailed sediment budget can be developed for Buttonland Swamp.

Surface and ground-water levels are being monitored at Heron Pond. A survey of the pond was conducted to determine its water storage capacity. From this survey and the water level records, a detailed water budget analysis will be performed. This will assist in assessing the future of the pond under different expected or assumed conditions of the Cache River in the vicinity of the pond.

In summary, the data collection program is in excellent shape and significant progress has been made. Valuable data are being collected under this program and there is no doubt that the data will be useful not only for formulating management alternatives but also as a basis for a long-term monitoring of the basin. As has been pointed out previously, data collected for this short period cannot and should not be considered representative of the variable hydrologic conditions of the basin. Thus the data collection program will continue for at least the three years for which it was originally designed.

Mathematical Modeling

Mathematical models are useful tools for investigating conditions under various assumed scenarios. Data collection alone is not sufficient to explain previous or future conditions because the length of data collection and variability of the conditions under which data are collected are usually limited and do not cover all possible conditions. Therefore it is imperative to use mathematical models when contemplating implementation of management alternatives. Mathematical models provide the capability of simulating expected conditions under assumed measures and provide the basis for selecting among alternative measures. For the Cache River basin, modeling could be applied for various reasons and applications. However, the application of models will be limited to the computation of flood flows, flood elevations, and the transport of sediment. These aspects of hydrology, hydraulics, and sediment transport of the basin have to be managed properly to resolve the various problems in the river basin.

Mathematical models will be applied to two separate areas in the Cache River basin. The first is the Post Creek Cutoff-upper Cache segment from the Ohio River to the Route 146 bridge upstream of the Little Black Slough wetland area. The primary consideration in this area is the entrenchment of the upper Cache River and its impacts on the wetlands, especially the area around Heron Pond. The second area where models will be applied is the lower Cache River reach from the Buttonland Swamp area to the mouth of the Cache River on the Mississippi River. The problems which will be investigated in this segment of the river include flood flows, floodwater elevations, and the sedimentation rate in Buttonland Swamp.

After several hydrologic and hydraulic models were evaluated, the HEC-6 model (U.S. Army Corps of Engineers, 1977) was selected as the best model on the basis of its capability, cost, and the nature of problems in the Cache River. The experience of the Water Survey staff in applying the HEC-6 model to investigate various hydraulic problems in the state and the satisfactory nature of the results from the model also played an important role in the model selection. Other models of similar capabilities were compared to the HEC-6; their results were found not to be any better, and they require more data and computer time. In addition, HEC-1 (U.S. Army Corps of Engineers, 1981) will be used to compute the streamflows into the Buttonland Swamp area resulting from various amounts of precipitation and other factors. Data obtained from monitoring will be used for calibration.

The segment of the Cache River identified as the Post Creek - upper Cache River segment will be modeled separately because it behaves independently from the lower Cache River. The only connection between the upper and lower basins is two 4-foot-diameter culverts in the Forman Floodway Levee, which are referred to as the "whistles." Under present conditions the influence of the whistles on the hydraulics of the Post Creek Cutoff is minimal. Flap gates prevent flow from the upper Cache River basin to the lower basin.

The application of the HEC-6 model to the upper Cache River reach is not yet complete. However, significant progress has been made in preparing the data and calibrating the hydraulic computation component. The sediment transport component will be developed and alternative solutions will be evaluated as more sediment data are collected and analyzed. Sediment discharge rating curves are now being developed and bed and bank material analyses are in progress. As those tasks are completed the sediment transport component of the model will be performed.

Preliminary model results for the Post Creek Cutoff - upper Cache River segment are presented in figures 14 and 15. The water surface elevations along the study reach for the 5-, 10-, 50-, and 100-year floods in the upper Cache River are shown in figure 14. The 5-year flood elevation in the Ohio River at Pool 53 was used as the downstream control elevation for this analysis. Also shown in the figure are the channel bed elevations and the low bank elevations along the study reach. For the most part, any major flood overtops the banks in the upper Cache River but is confined within the banks of the Post Creek Cutoff.

The influence of the Ohio River water surface elevations for various flood frequencies on the 100-year flood elevations along the Post Creek Cutoff and the upper Cache River is shown in figure 15. As shown in the figure, the water surface elevation in the Ohio River influences the flood elevation in the Post Creek Cutoff and the upper Cache River all the way upstream to the Forman gaging station. The influence is more pronounced for the more frequent floods than for less frequent floods.

The development of the model for the lower Cache River segment is in progress. However, because of the scarcity of geometric data, the model is not as well developed as the model for the Post Creek Cutoff - upper Cache River segment. A preliminary working model for this segment should be ready during this project year.

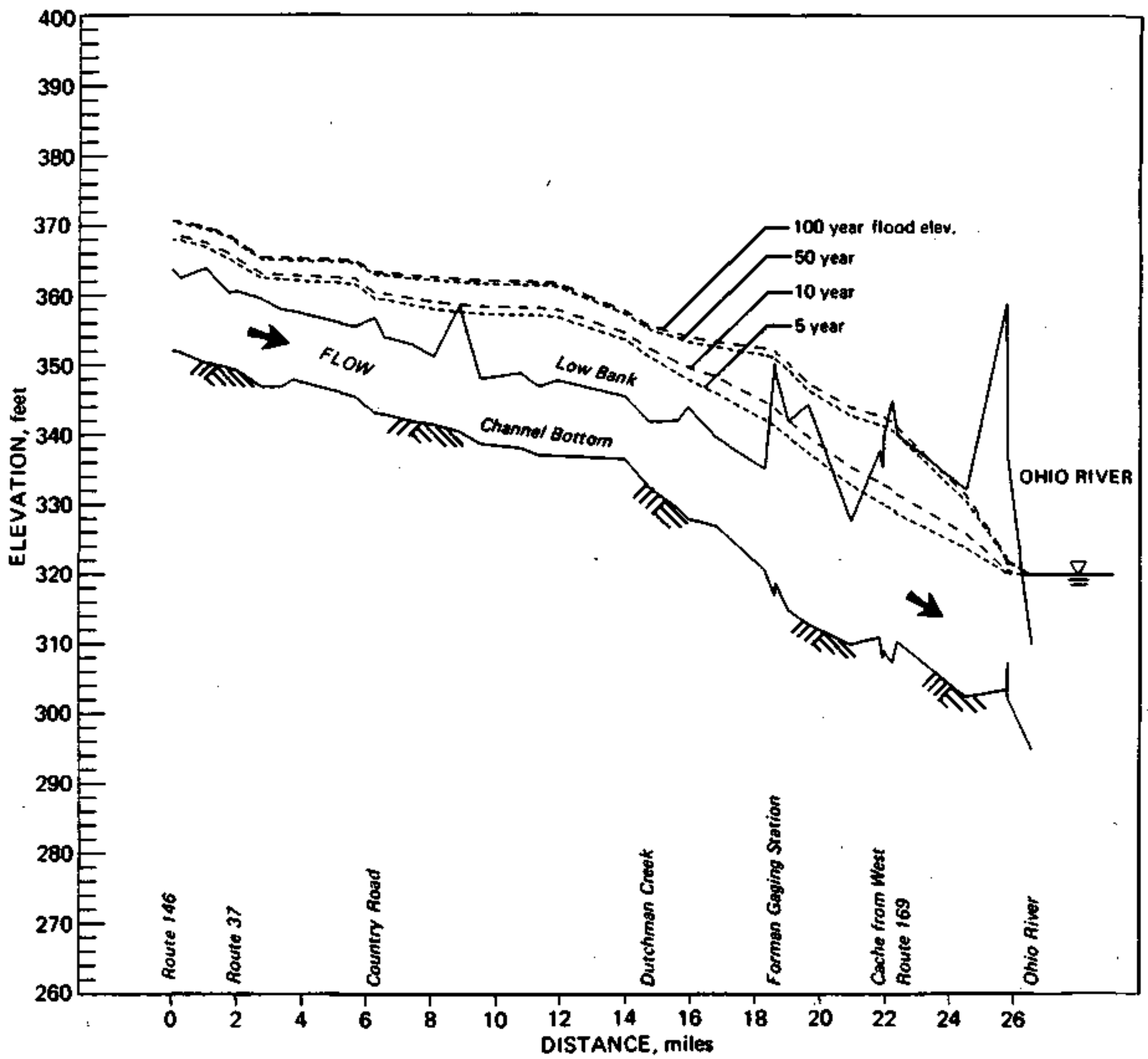

Figure 14. Flood elevations along the Post Creek Cutoff - upper Cache River segment (the stage on the Ohio River corresponds to the 5-year flood elevation)

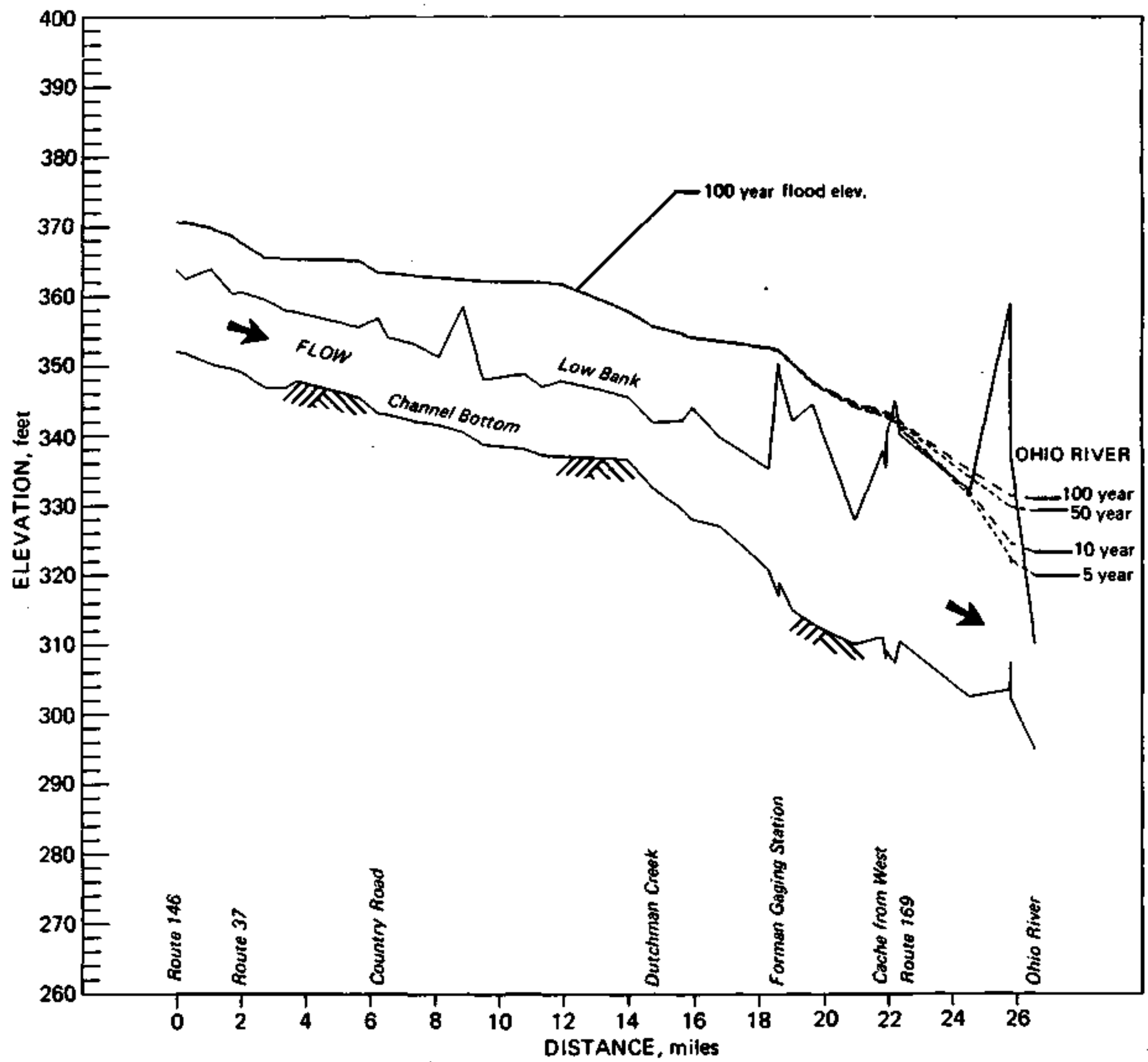

Figure 15. Influence of Ohio River stages on the 100-year flood elevations along the Post Creek Cutoff - upper Cache River segment (the stages on the Ohio River correspond to the 100-, 50-, 10-, and 5-year flood elevations)

Alternative Solutions to Hydrologic Problems in the Basin

Up to the present, most of the efforts on the project have been to establish and improve the data collection program, review previous studies, and develop appropriate models to evaluate the problems. Although those efforts will continue, the process of developing and evaluating all the possible alternative solutions will become a major task in the near future.

The initial step in this process is to list and discuss all the alternative solutions. This will require input from other agencies and groups, although an initial list will be developed by the Water Survey. The next step will be to evaluate the effectiveness of each alternative and to compare different alternatives. This process will utilize the data collected to date and the models under development. On the basis of the comparative analysis, a list of recommendations will be developed and submitted to the Cache River Task Force and other interested groups for review and comments. The final recommendations will consider the comments and suggestions received from all interested groups and agencies.

ACKNOWLEDGMENTS

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REFERENCES

U.S. Army Corps of Engineers. March 1977. HEC-6, Scour and Deposition in Rivers and Reservoirs, User's Manual. The Hydrologic Engineering Center, Davis, California.

U.S. Army Corps of Engineers. September 1981. HEC-1, Flood Hydrograph Package, User's Manual. The Hydrologic Engineering Center, Davis, California.